MSFC Combustion Devices in 2001

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TD61 – Functional Design Group

- TD - Space Transportation Directorate
- TD60 - Subsystem & Component Development Department
- TD61 - Functional Design Group, Henry Stinson - Group Lead
  - Combustion Devices Team
  - Turbomachinery Team
- Overall responsibility
  - Test requesting organization for technology and advanced liquid rocket engine component development activities
  - Support the SSME, ASTP, and Gen 2 organizations
- Examples of current combustion devices technology and advanced development activities
  - NRA8-21 Task for RLV Focus Technology
    - Lightweight, Long Life Thrust Cells
    - Lightweight Injectors
  - Liquid/Liquid Preburner Task
  - Vortex Thrust Chamber

TD61 – Functional Design Group

Combustion Devices Team

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NRA8-21 Task for RLV Focus Technology

Space Transportation Directorate

Lightweight, Long Life Thrust Cells

Objectives:

Reduce thrust assembly weights to create lighter engines, Increase cycle life and/or operating temperatures

Team:

Marshall Space Flight Center (MSFC)
Glenn Research Center (GRC)
Rocketdyne Division of The Boeing Company
Additional Contractors

Task Lead: Sandy Elam/MSFC TD61

Material Options & Contractors

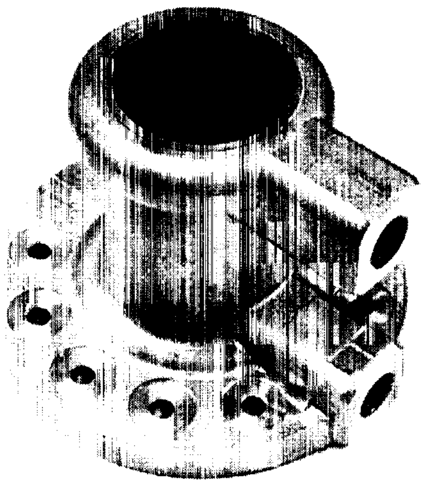
Reduce Weight
Polymer Matrix Composites (PMC)
Metal Matrix Composites (MMC)

Improve Life & Operating Temperatures
Ceramic Matrix Composites (CMC)
Advanced Copper Alloy (GRCop-84)

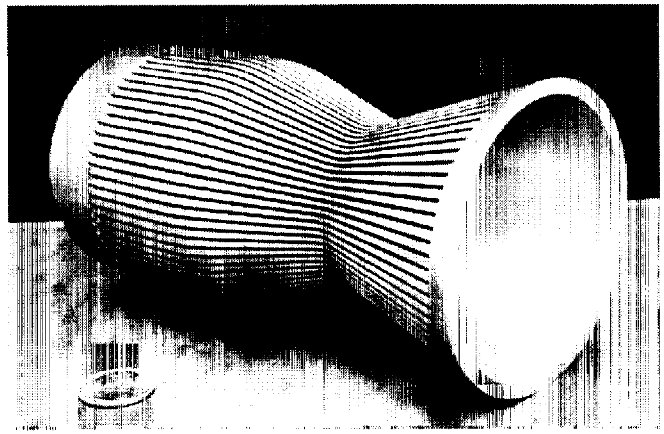
Contractor	Material System	
Hyper-Therm, Inc.	CMC	SiC/SiC liner
Ceramic Composites, Inc. (CCI)	CMC	C/C liner
Plasma Processes, Inc. (PPI)	PMC	Fiber/Epoxy Overwrap
Lockheed Martin Astronautics (LMA) Composite Optics, Inc. (COI)	PMC	Fiber/Epoxy Overwrap
Aerojet	PMC	Fiber/Epoxy Overwrap
Plasma Processes, Inc. (PPI)	MMC	VPS Al/SiC
MSE Technology Applications	MMC	Cast Al/SiC

GRCop-84 Liner was used in all PMC & MMC Units

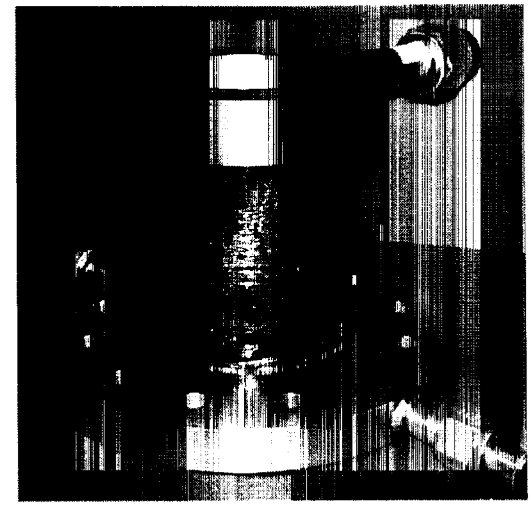
MMC & PMC Subscale Units



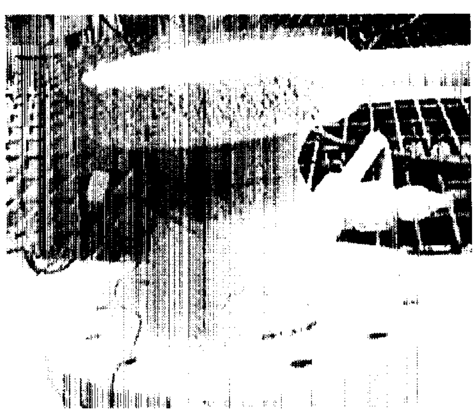
Aluminum Metal Matrix Composite (Al-MMC) Jacket & Manifolds

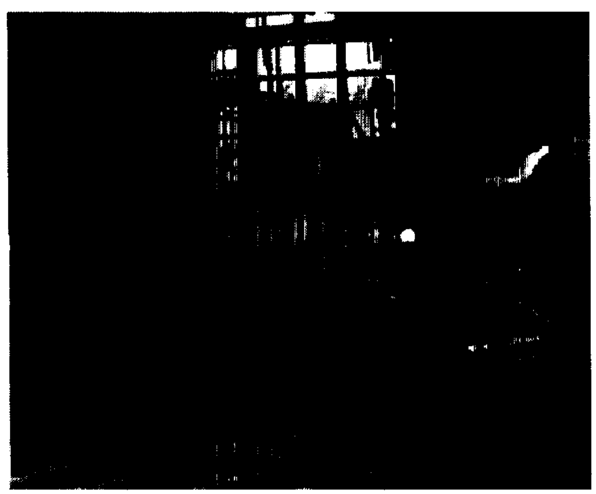


Advanced Copper Alloy (GRCop-84) Liner Improves Life & Operating Temperatures



Polymer Matrix Composite (PMC) "Overwrap" Jacket

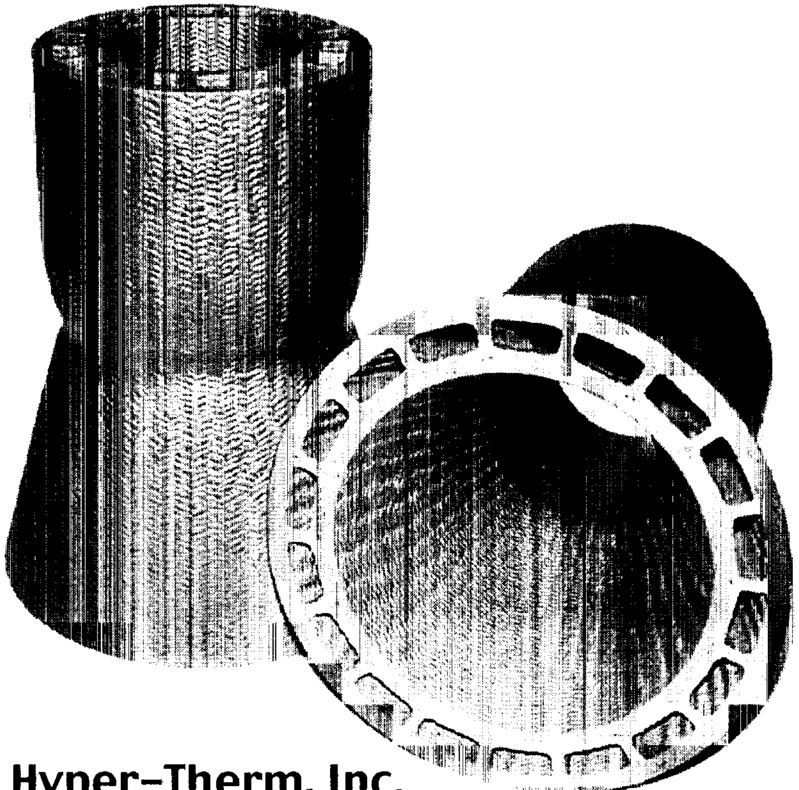


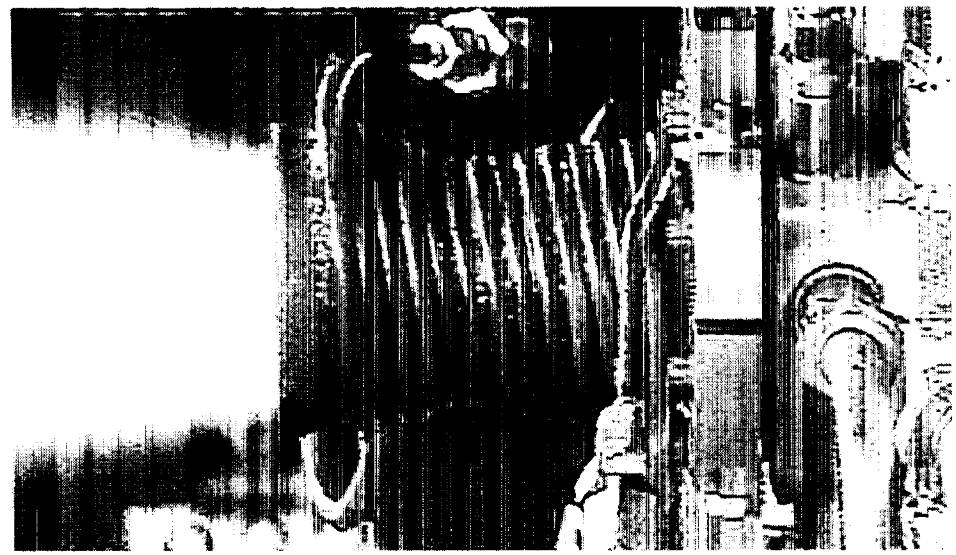


Cryogenic &
Hot-fire Testing at MSFC Validated Materials

50% Lighter than Conventional Designs with Traditional Steel and Copper Alloys

CMC Subscale Liners





Hyper-Therm, Inc.

Silicon Carbide (SiC)/SiC Liner with Integral Cooling Channels

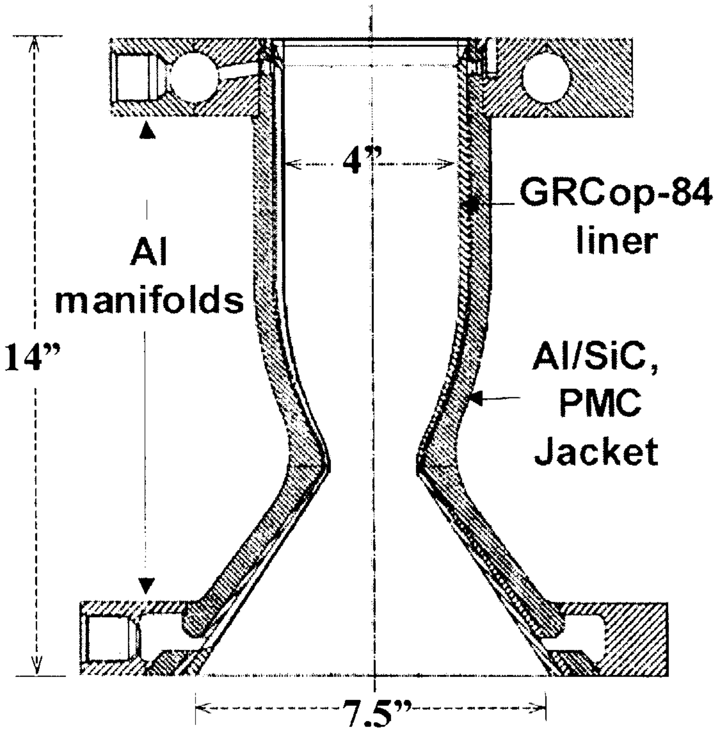
Ceramic Composites, Inc. (CCI)

Carbon (C)/C Liner Cooled with Bonded Copper Tubing

Hot-fire Testing Performed on Both Concepts at NASA-GRC

Hot Wall Temperatures > 3000 deg F

Full Size Chambers



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Applying Selected Materials & Processes to "Full Size" Chamber Designs...

2 Designs

(1) MMC, (1) PMC Jacket

Planned Test Conditions

LOX/GH2 Propellants

LH2 Cooling

Pc = 2400 psia, MR ~ 6.0

Thrust ~ 15,000 lbs

Hot-fire Testing at MSFC in 2001

Test results will directly compare

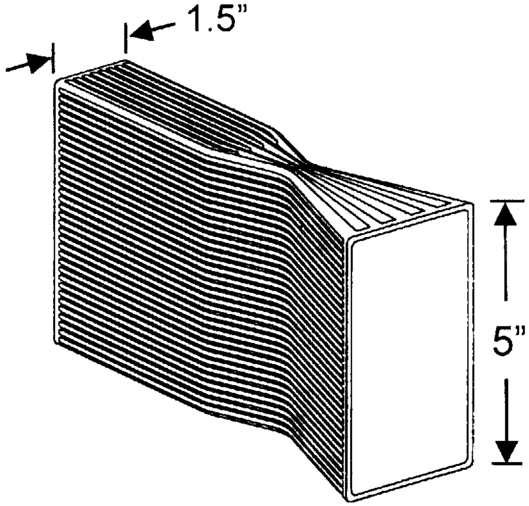
conventional chamber vs. lightweight design

Lightweight Linear Chamber

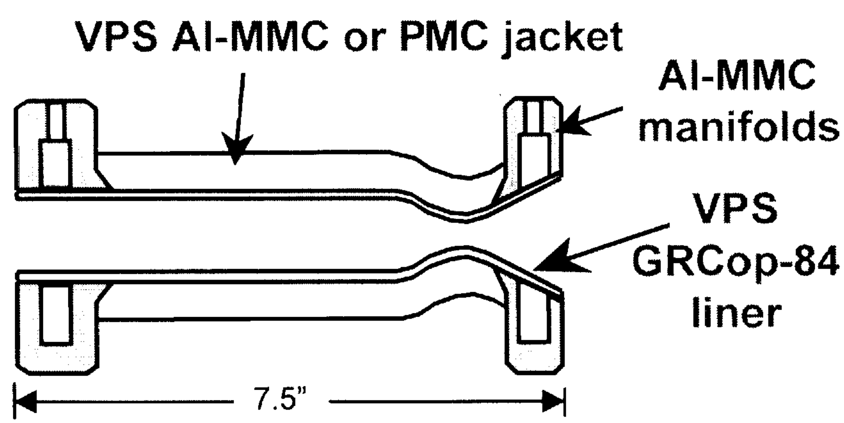
MSFC CDDF Task

Objective:
Demonstrate Versatility of "Lightweight" Chamber Technology Developed in NRA Task

Preliminary Design



Liner



Assembly

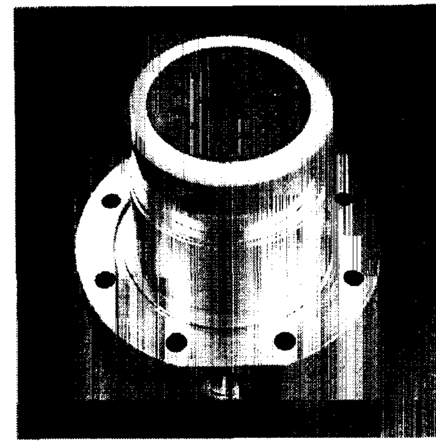
- Applying PMC & MMC Concepts to Rectangular (2D) Chamber Design
- Fabricating 2 Complete Chambers to mate with existing 2D injector
- No current plans to hot-fire test

Task Lead: Sandy Elam/MSFC TD61

Lightweight Injector Development

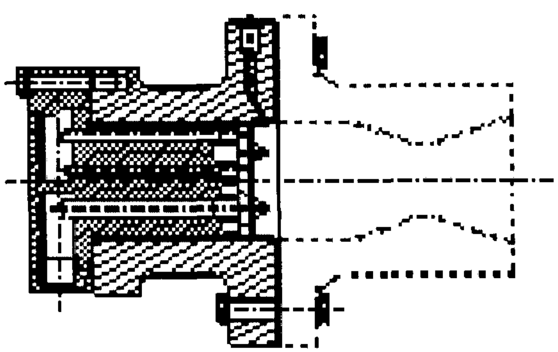
MSFC CDDF Task

Objective:
Apply Composite Materials to Injector Designs



Conceptual Coaxial Injector Demo Unit

- **Approach:**
  - Develop braze processes with material samples
  - Fabricate subscale composite injectors
  - Hot-fire test w/subscale chamber from NRA8-21



Test Assembly

- **Demonstrate 2 Designs for LOX/GH2**
  - Coaxial Injector
  - Impinging Injector
- **Material Candidates**
  - Housing/Manifolding: Al MMC
  - Faceplates: Cu alloy
  - Interface rings: Stainless Steel

Task Lead: Sandy Elam/MSFC TD61

Liquid/Liquid Preburner Task

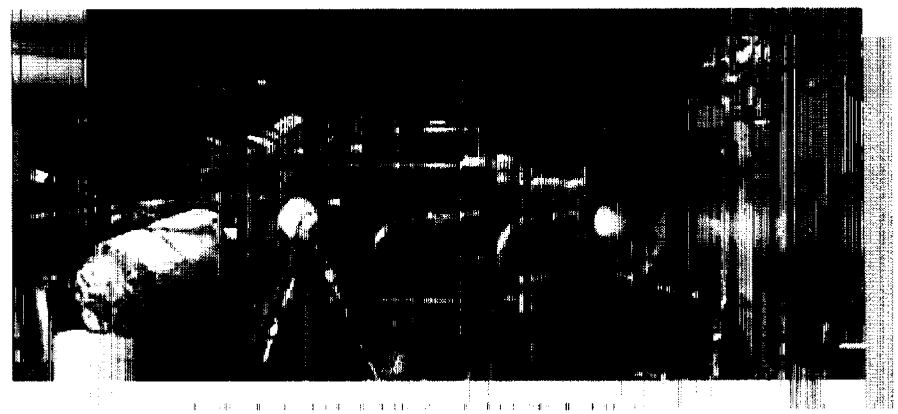
Space Transportation Directorate

MSFC Gen 2 Risk Mitigation Task

Objective:

Provide risk mitigation for development of a liquid oxygen/liquid hydrogen preburner

- Approach:
  - **Perform CFD analyses on preburner injector designs based on RS-83 and COBRA preburner concepts**
  - **Perform single-element and multi-element testing at TS115**
  - **Anchor CFD model with data collected at TS115**
  - **Anchor CFD model with COBRA and RS-83 subscale test data**



MCTA testing at TS115

Task Leads: Amy Reeb/MSFC TD61 and Kevin Tucker/MSFC TD64

Liquid/Liquid Preburner Task

Planned Single- Element Test Conditions

LOX/LH_2 Propellants

Pc = 1800 psia (~28% power level), due to test facility limitations

Mixture Ratio = 0.67

Test Duration ~ 10 seconds

Liquid Oxygen System

LOX flowrate = 0.285 lbm/sec

LOX temp = 170 R

Liquid Hydrogen System

LH_2 flowrate = 0.426 lbm/sec

LH_2 temp = 91 R

GH_2 Barrier Flow

GH_2 flowrate = TBD lbm/sec

GH_2 temp = 532 R

Liquid/Liquid Preburner Task

Planned Multi- Element Test Conditions

LOX/LH_2 Propellants
7 Elements
Pc = 1800 psia, due to test facility limitations
Mixture Ratio = 0.67
Test Duration ~ 10 seconds Mainstage

Liquid Oxygen System

LOX flowrate = 1.34 lbm/sec
LOX temp = 170 R

Liquid Hydrogen System

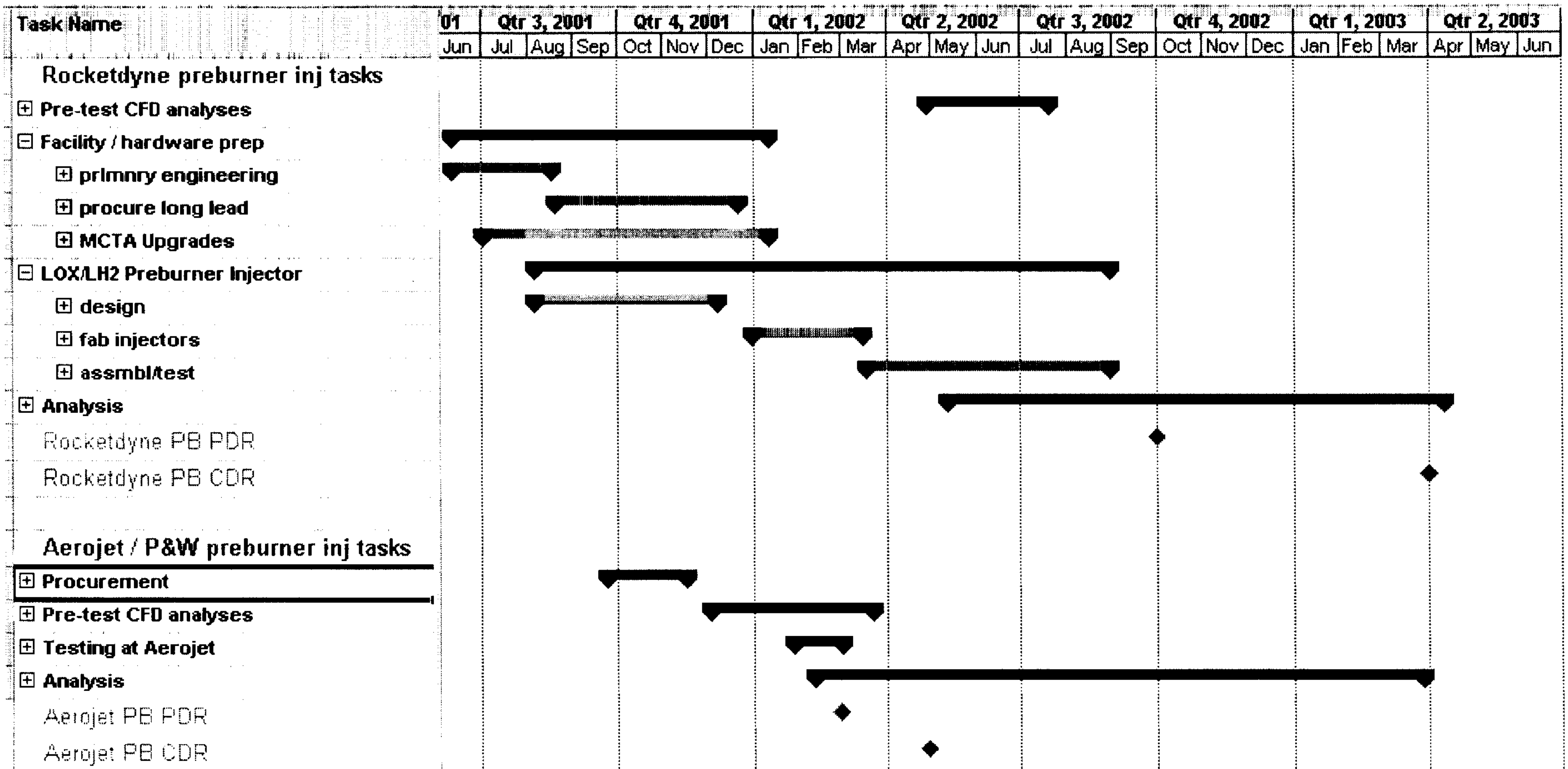
LH_2 flowrate = 2.0 lbm/sec
LH_2 temp = 91 R

GH_2 Barrier Flow*

GH_2 flowrate = TBD lbm/sec
GH_2 temp = 532 R

*Unknown at this time whether GH2 will be required

Liquid/Liquid Preburner Task Schedule



Vortex Chamber Task

MSFC CDDF and ASTP Tasks

Objective:
Evaluate Vortex chamber concepts for liquid rocket engine applications

Team:
Marshall Space Flight Center (MSFC)
Orbital Technologies Corporation (Orbitec)
U.S. Army Missile Command

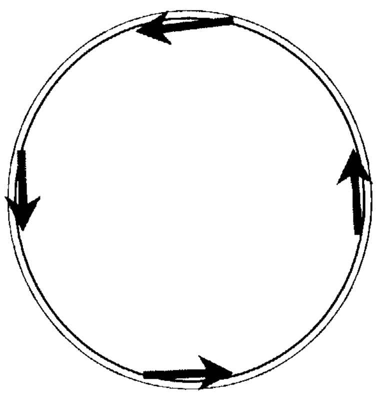
Streamline Traces Between Injector Holes of the Vortex Engine

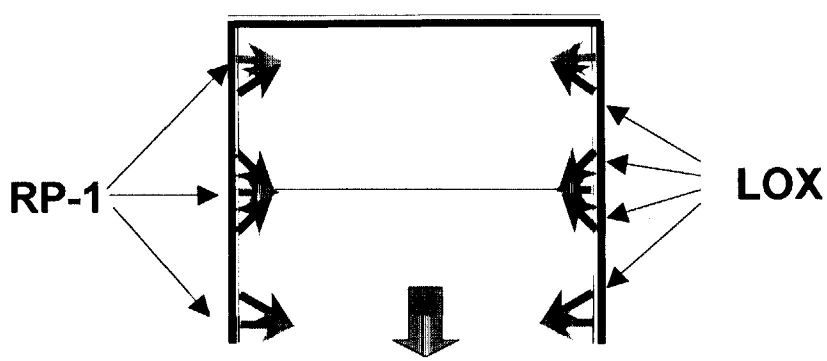
- **Approach:**
  - **Design and test 1000 lbf thrust class Vortex thruster**
    - **MSFC and the Army to test Impinging Stream Vortex (ISVE) concept at MSFC TS115**
      - **ISVE hardware will also be used to demonstrate and validate:**
        - **Laser Ignition and combustion wave ignition for LOX/RP-1**
        - **Raman and emission/absorption exhaust plume measurement methods**
    - **Orbitec to test Vortex Combustion Cold Wall (VCCW) concept at Orbitec**
  - **Anchor CFD models with test data**
  - **Use validated models to optimize design of vortex chamber≈**

Task Leads: Brad Bullard/MSFC TD61 and Huu Trinh/MSFC TD61

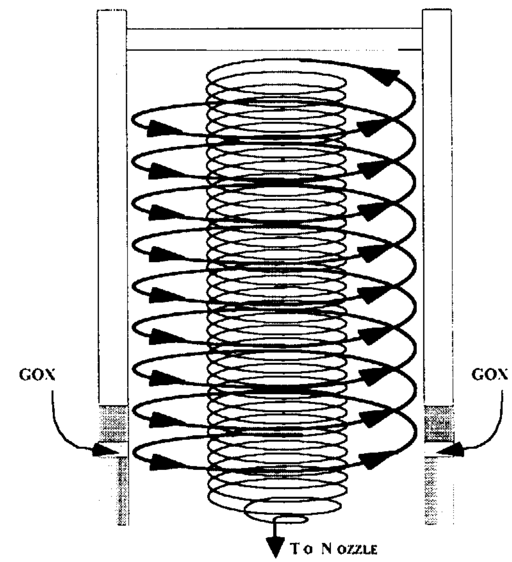
Vortex Chamber Task

<u>Vortex Chamber Concept:</u>
Flow vortices are generated by injecting propellant tangentially to the chamber wall





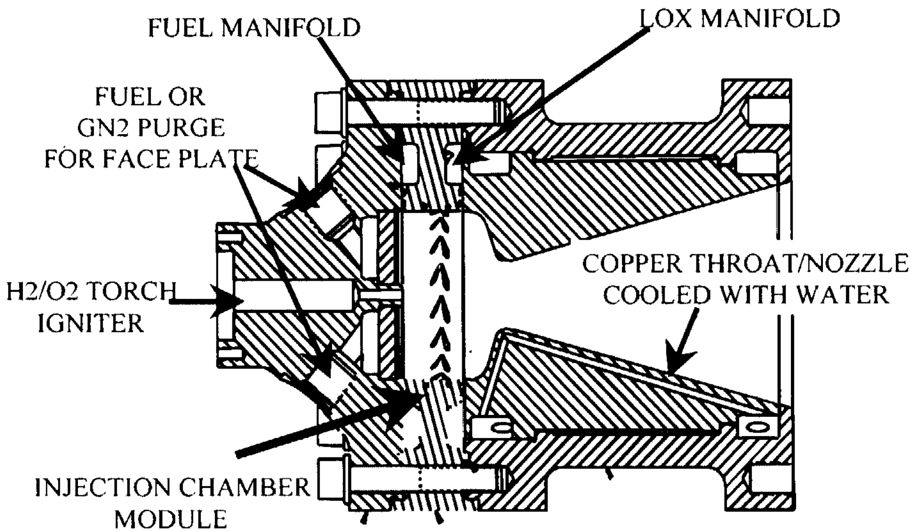
Multi-Plan Impinger



Vortex Chamber Flow Schematic

- Due to the centrifugal force, relatively cooler propellant streams tend to flow along the chamber wall
- Vortex flow promotes the propellant mixing process
- Swirling flow motion creates a longer flow path

Vortex Chamber Task



Test Hardware

ISVE Thruster Test Conditions

LOX/RP-1 Propellants
Pc = 1000 psia
Ideal Vacuum Thrust = 1250 lbf
Mixture Ratio = 2.6
Throat Dia. ~ 1 in
Chamber Dia. ~ 3 in
Nozzle Exit Dia. ~ 3.11 to 3.5 in